

## Environmental Impact Assessment of U.S. Air Force Launches from Kodiak, Alaska

1 May 2001

Prepared by

V. I. LANG,<sup>1</sup> T. HUYNH,<sup>2</sup> A. BOWLES,<sup>3</sup>  
B. STEWART,<sup>3</sup> and K. PLOTKIN<sup>4</sup>

<sup>1</sup>Systems Planning & Engineering Group  
The Aerospace Corporation  
Los Angeles, CA 90009

<sup>2</sup>United States Air Force  
Los Angeles AFB, CA 90245

<sup>3</sup>Hubbs-Sea World Research Institute  
San Diego, CA 92109

<sup>4</sup>Wyle Laboratories  
Arlington, VA 22202

Prepared for

SPACE AND MISSILE SYSTEMS CENTER  
AIR FORCE MATERIEL COMMAND  
2430 E. El Segundo Boulevard  
Los Angeles Air Force Base, CA 90245

Systems Planning and Engineering Group

APPROVED FOR PUBLIC RELEASE;  
DISTRIBUTION UNLIMITED



**THE AEROSPACE  
CORPORATION**  
El Segundo, California

20010703 047

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245-4691, under Contract No. F04701-00-C-0009 with the Space and Missile Systems Center, 2430 E. El Segundo Blvd., Los Angeles Air Force Base, CA 90245. It was reviewed and approved for The Aerospace Corporation by W. H. Goodman, Systems Director, Office of Chief Architect/Engineer. John Edwards was the project officer for the program.

This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

A handwritten signature in black ink, appearing to read 'John L. Edwards', with a long horizontal flourish extending to the right.

John Edwards  
SMC/AXFV

| REPORT DOCUMENTATION PAGE  |                             |                              |                            | Form Approved<br>OMB No. 0704-0188                       |   |
|--|-----------------------------|------------------------------|----------------------------|--|---|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS. |                             |                              |                            |  |   |
| 1. REPORT DATE (DD-MM-YYYY)<br>1 May 2001  |                             | 2. REPORT TYPE               |                            | 3. DATES COVERED (From - To)                             |   |
| 4. TITLE AND SUBTITLE<br>Environmental Impact Assessment of U.S. Air Force Launches from Kodiak, Alaska  |                             |                              |                            | 5a. CONTRACT NUMBER<br>F04701-00-C-0009                  |   |
|  |                             |                              |                            | 5b. GRANT NUMBER   |   |
|  |                             |                              |                            | 5c. PROGRAM ELEMENT NUMBER                               |   |
| 6. AUTHOR(S)<br>V. I. Lang, T. Huynh, A. Bowles, B. Stewart, and K. Plotkin  |                             |                              |                            | 5d. PROJECT NUMBER                                       |   |
|  |                             |                              |                            | 5e. TASK NUMBER  |   |
|  |                             |                              |                            | 5f. WORK UNIT NUMBER                                     |   |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>The Aerospace Corporation<br>Systems Planning & Engineering Group<br>El Segundo, CA 90245-4691   |                             |                              |                            | 8. PERFORMING ORGANIZATION REPORT<br><br>TR-2001(1306)-2 |   |
| 9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>Space and Missile Systems Center<br>Air Force Materiel Command<br>2430 E. El Segundo Blvd.<br>Los Angeles Air Force Base, CA 90245  |                             |                              |                            | 10. SPONSOR/MONITOR'S ACRONYM(S)<br>SMC                  |   |
|  |                             |                              |                            | 11. SPONSOR/MONITOR'S REPORT NUMBER(S)<br>SMC-TR-01-14   |   |
| 12. DISTRIBUTION / AVAILABILITY STATEMENT<br>Approved for public release; distribution unlimited.  |                             |                              |                            |  |   |
| 13. SUPPLEMENTARY NOTES  |                             |                              |                            |  |   |
| 14. ABSTRACT<br><br>A comparison between noise predictions made with the RNOISE computation model and actual monitoring data, for two USAF atmospheric interceptor technology (ait) Program launches from the Kodiak Launch Complex (KLC), is presented. Maximum A-weighted sound pressure levels ( $L_{AMAX}$ ) recorded at locations within 2 km of the launch site ranged from approximately 103 to 105 dB for the two launch vehicles. A-weighted sound exposure levels (ASEL) from the same area ranged from approximately 109 dB to 113 dB. At 5.7 km from the launch site, in the vicinity of a haulout for endangered Steller sea lions, the measured ait-1 $L_{AMAX}$ was reduced to approximately 78 dB while the ASEL was approximately 88 dB. The latter values agreed well with A-weighted sound levels predicted using RNOISE for the same location.   |                             |                              |                            |  |   |
| 15. SUBJECT TERMS<br>Noise monitoring, Kodiak Launch Complex, Launch, Steller sea lion   |                             |                              |                            |  |   |
| 16. SECURITY CLASSIFICATION OF:  |                             |                              | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES<br><br>15                            | 19a. NAME OF RESPONSIBLE PERSON<br>Valerie Lang               |
| a. REPORT<br>UNCLASSIFIED  | b. ABSTRACT<br>UNCLASSIFIED | c. THIS PAGE<br>UNCLASSIFIED |                            |  | 19b. TELEPHONE NUMBER<br>(include area code)<br>(310)336-1170 |

## **Acknowledgments**

The authors would like to thank Ed Casey and Cameron Purcell of The Aerospace Corporation for generating GIS data maps and providing geographic analyses. Sal Cuccarese and Mike Kelly of University of Alaska, ENRI coordinated closely with the AF team and provided valuable support for both launches, although their findings are published separately. The work was supported by the AF ait program office (Mel Herrera and Michael Watt) and the SMC Environmental Management office (John Edwards). This report was prepared under USAF Contract No F04701-93-C-0094.

This paper was originally included in the Proceedings of the 20<sup>th</sup> Annual Meeting of the International Association for Impact Assessment (IAIA), June 2000, Hong Kong.

## Contents

|                                       |    |
|---------------------------------------|----|
| 1. Introduction.....                  | 1  |
| 2. Location .....                     | 3  |
| 3. ait Launches .....                 | 5  |
| 4. Monitoring .....                   | 7  |
| 5. Results.....                       | 9  |
| 5.1 ait-1 Launch, November 1998.....  | 9  |
| 5.2 ait-2 Launch, September 1999..... | 10 |
| 6. Discussion.....                    | 13 |
| 7. References.....                    | 15 |

## Figures

|  |    |
|--|----|
| 1. Kodiak Launch Complex and vicinity.....   | 3  |
| 2. ait-1 predicted vs. measured A-weighted sound exposure level (ASEL).....                  | 9  |
| 3. ait-1 predicted vs. measured A-weighted maximum sound pressure levels ( $L_{AMAX}$ )..... | 10 |
| 4. ait-2 predicted vs. measured A-weighted sound exposure levels (ASEL).....                 | 11 |
| 5. ait-2 predicted vs. measured A-weighted maximum sound pressure levels ( $L_{AMAX}$ )..... | 12 |

## 1. Introduction

In November 1998, the United States Air Force (USAF) launched the first of two atmospheric interceptor technology (ait) suborbital vehicles from the Kodiak Launch Complex (KLC), located on Kodiak Island, Alaska. This was the first launch (either government or commercial) from the Alaska state-operated facility, which opened in 1998. The second atmospheric interceptor technology (ait-2) launch took place in November 1999.

In 1997, the USAF completed an Environmental Assessment (EA) (USAF, 1997) and signed a Finding of No Significant Impact (FONSI) for the ait launches, according to National Environmental Policy Act (NEPA) requirements. The USAF was required to monitor the potential impacts of each of the two ait launches on endangered or threatened species. The Federal Aviation Administration (FAA) [in collaboration with the Alaska Aerospace Development Corporation (AADC)] prepared a separate EA for KLC (AADC, 1996), and, therefore, has a separate obligation to monitor the first five launches from the site, under the terms of their consultations with the United States Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS).

USAF monitoring efforts have focused on the potential effects of launch noise on the Steller sea lion. The Steller sea lion is on the federal list of endangered species and is protected under both the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). The Steller's eider, a threatened sea duck in the vicinity, is also protected under the ESA. Only potential noise impacts to the Steller sea lion were considered in this USAF study because the University of Alaska, Environmental and Natural Resources Institute (ENRI) (AADC, 1998) was responsible for monitoring the birds. Other species that inhabit the vicinity of the launch corridor include gray whales and bald eagles.

Prior to each of the ait launches, predictions of on-pad and in-flight noise were made using the RNOISE computer code. During each of the ait-1 and ait-2 launch periods, digital audio tape (DAT) recorders and sound level meters were deployed (Stewart, 1999; Bowles, 2000). The monitoring sites included one on Ugak Island where a seasonal Steller sea lion haulout is located.

The presence of Steller sea lions at the Ugak Island haulout during the ait-2 launch period allowed for opportunistic observations of their behavior, which is described in Bowles, 2000. The sea lions were not present during the ait-1 launch; however, the noise data provided ground truthing for the model results.

Representative data from the ait-1 and ait-2 monitoring campaigns are presented in this summary report. A collaborative team consisting of the USAF, Hubbs-Sea World Research Institute (HSWRI), The Aerospace Corporation, and Wyle Laboratories contributed to the work. A list of detailed reports resulting from the monitoring efforts is provided in Section 7.

## 2. Location

The Kodiak Launch Complex is located on Narrow Cape, Kodiak Island, Alaska. The locations of the launch site, as well as the seasonal Steller sea lion haulout on Ugak Island, are shown in Figure 1. The launch complex is under development by the Alaska Aerospace Development Corporation. The adjacent land includes state recreational facilities as well as ranchland.

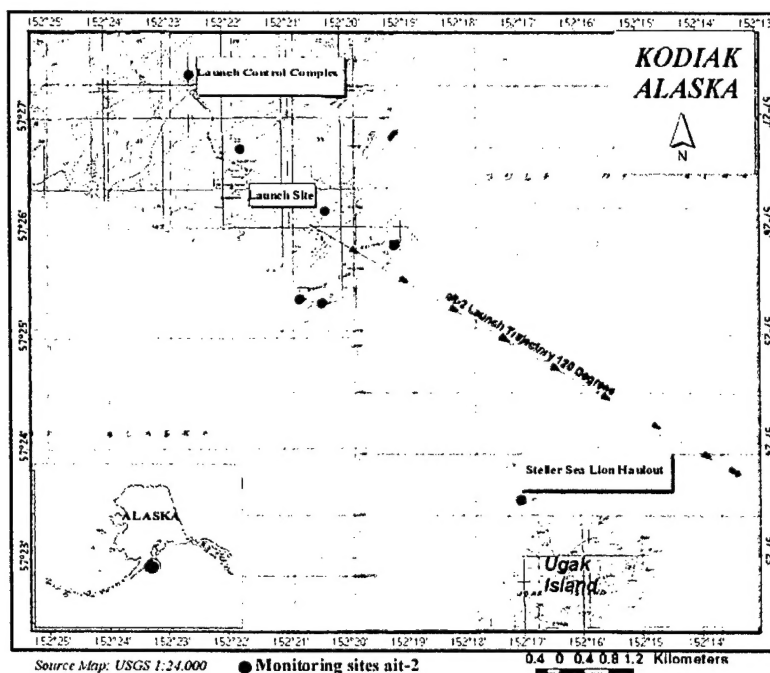


Figure 1. Kodiak Launch Complex and vicinity.

### 3. ait Launches

The ait-1 and ait-2 sub-orbital vehicles each consisted of two solid-propellant rocket stages. The larger of these, the ait-2 launch vehicle, was approximately 17.3 m long and weighed 11,910 kg at liftoff. The vehicles were launched from a portable stool located near the permanent KLC Launch Pad and Service Structure shown as the launch site in Figure 1. The second stage of each vehicle terminated in the Pacific Ocean after following a southern trajectory along the west coast of the continental United States. The overflight area of both launches was the Gulf of Alaska, northeast of Ugak Island. The ground path of the ait-2 launch trajectory is shown in Figure 1. The closest approach of the vehicle to the sea lion haulout on Ugak Island was 13.5 km slant distance for ait-1 and 14.8 km for ait-2.



#### 4. Monitoring

HSWRI was responsible for deploying and operating the noise monitoring equipment for the USAF ait-1 and ait-2 launches. Monitoring was conducted from three sites in 1998 and from five sites in 1999. Detailed descriptions of the equipment and their mode of operation are given in *Stewart, 1998* and *Bowles, 2000*. Larson-Davis sound-level meters (Models 820 and 824) were used for unattended collection of detailed information about noise events. The sound meters were set to record noise above a software-adjustable threshold. Calibrated real-time launch recordings were made with a digital audio tape recorder (TEAC RD101T DAT) with a flat response microphone (ACO 7013; 12 Hz-20 kHz). In addition to the actual launch events, background ambient noise levels were recorded prior to and after the launches. ENRI carried on a coordinated and parallel monitoring effort, which is described elsewhere (*Bowles, 2000*).

Before and after the ait-2 launch, a Meade ETX-90EC telescope was used to observe and photograph the Steller sea lions on Ugak Island. The observations were made from sites on Narrow Cape that were 4.5–5.0 km from the haulout (*Lang, 2000*). The sea lions were also observed from a closer site on Ugak Island the evening before the ait-2 launch. Due to range safety constraints, observers were not allowed within the debris impact zone during the launch.

## 5. Results

Although unweighted, C-weighted, and A-weighted sound pressure data have been considered in the assessment of potential launch noise impacts on the Steller sea lions, only representative A-weighted data are presented here. A-weighting is based on the human response to sound, which is reduced at <1 kHz and >6kHz. Similar filter functions have yet to be determined and standardized for marine mammals. A more detailed discussion of the appropriate filter weighting for marine mammal applications can be found in *Bowles, 2000*. A discussion of frequency responses of marine mammal auditory systems can be found in *Richardson et al., 1995*.

### 5.1 ait-1 Launch, November 1998

Since this launch occurred in the month of November, the endangered Steller sea lions were not present. Figures 2 and 3 compare maximum A-weighted sound pressure levels ( $L_{AMAX}$ ) and A-weighted sound exposure levels (ASEL) measured during the ait-1 launch to noise levels predicted with RNOISE.\* The predictions are shown as sound level contour lines. The sound event durations for ait-1 are given in *Stewart, 1999*.

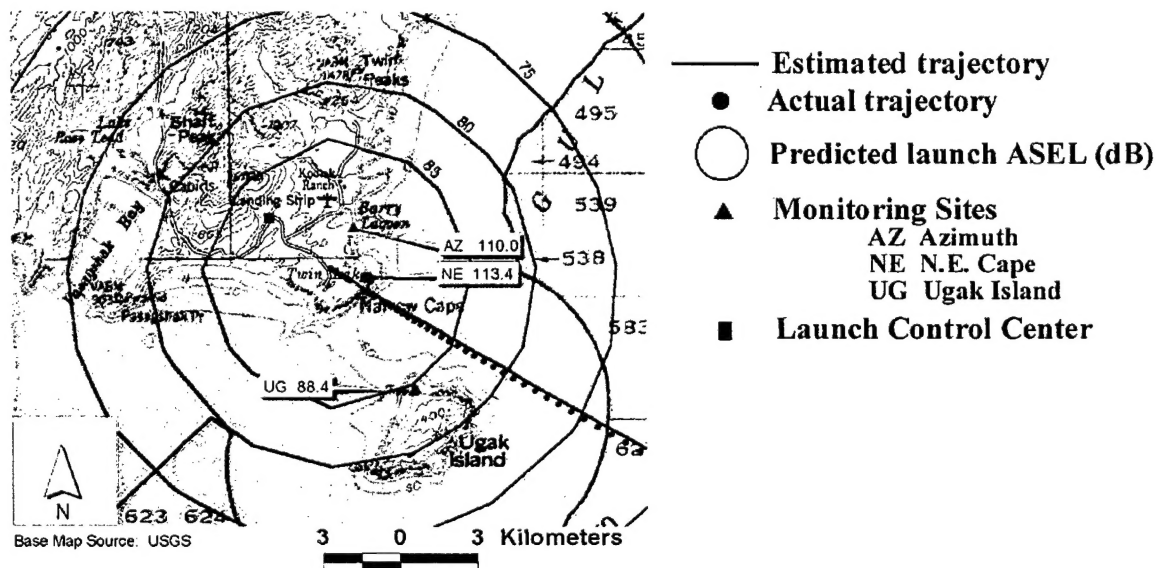


Figure 2. ait-1 predicted vs. measured A-weighted sound exposure level (ASEL). RNOISE predictions made by K. Plotkin of Wyle Labs and the sound pressure levels recorded by B. Stewart of HSWRI.

\*A maximum sound pressure level for a noise event is determined from the greatest of average root-mean-square instantaneous sound pressure levels during either 125-ms (fast time averaging) or 1-s (slow time averaging) periods. The representative maximum sound pressure levels reported here were calculated with slow time averaging and were further A-weighted ( $L_{AMAX}$ ). The sound exposure level (SEL) is a measure of the integrated energy in a noise event. For ait-2, maximum sound pressure levels were measured with instruments set for both fast and slow response; however, only the latter are given here for comparison to the RNOISE calculations. RNOISE predictions were computed at 1-s intervals, but do not account for fluctuations associated with atmospheric conditions.

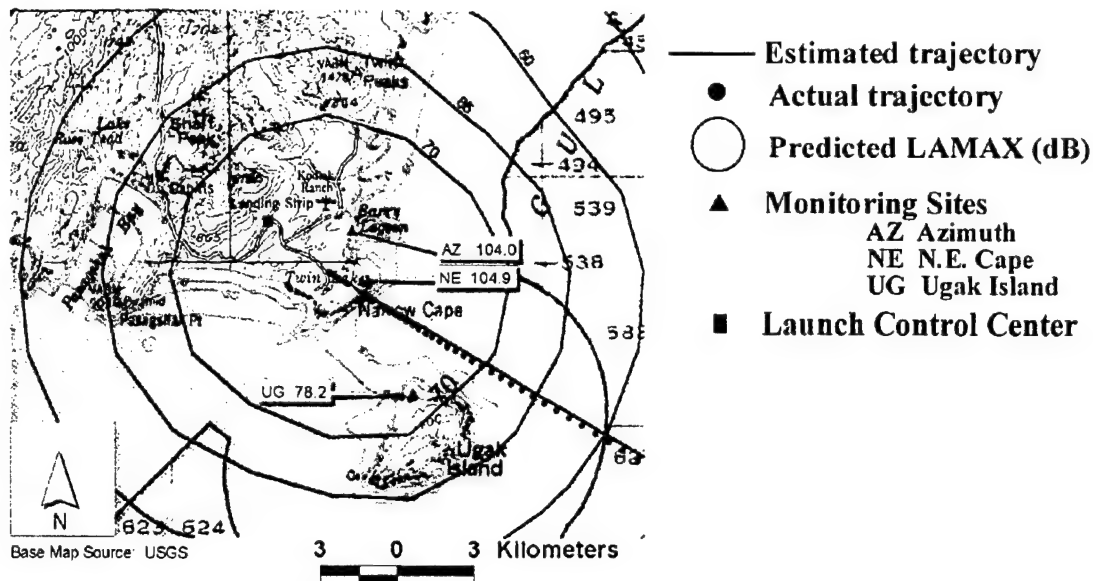


Figure 3. ait-1 predicted vs. measured A-weighted maximum sound pressure levels ( $L_{AMAX}$ ). RNOISE predictions made by K. Plotkin of Wyle Labs and the sound pressure levels recorded by B. Stewart of HSWRI.

The measured ASEL values for the ait-1 launch were 113.4 dB at approximately 1.5 km from the launch event; 110.0 dB at approximately 2 km; and 88.4 dB at 5.7 km. The latter corresponds to the sea lion haulout area on Ugak Island. These values indicate a decrease in noise levels with increasing distance from the launch event. The  $L_{AMAX}$  levels for the same locations were 104.9 dB, 104.0 dB, and 78.2 dB, respectively. While a considerable decrease in the sound level is evident between locations on Narrow Cape and the one on Ugak Island, other trends in the noise levels are difficult to ascertain from this limited data.

The RNOISE predicted ASEL for the Ugak Island site was 85 dB, while the predicted  $L_{AMAX}$  is extrapolated to between 70 and 75 dB. The predicted ASEL value is somewhat closer to the measured ASEL value of 88.4 dB than the  $L_{AMAX}$  prediction is to the  $L_{AMAX}$  measurement.

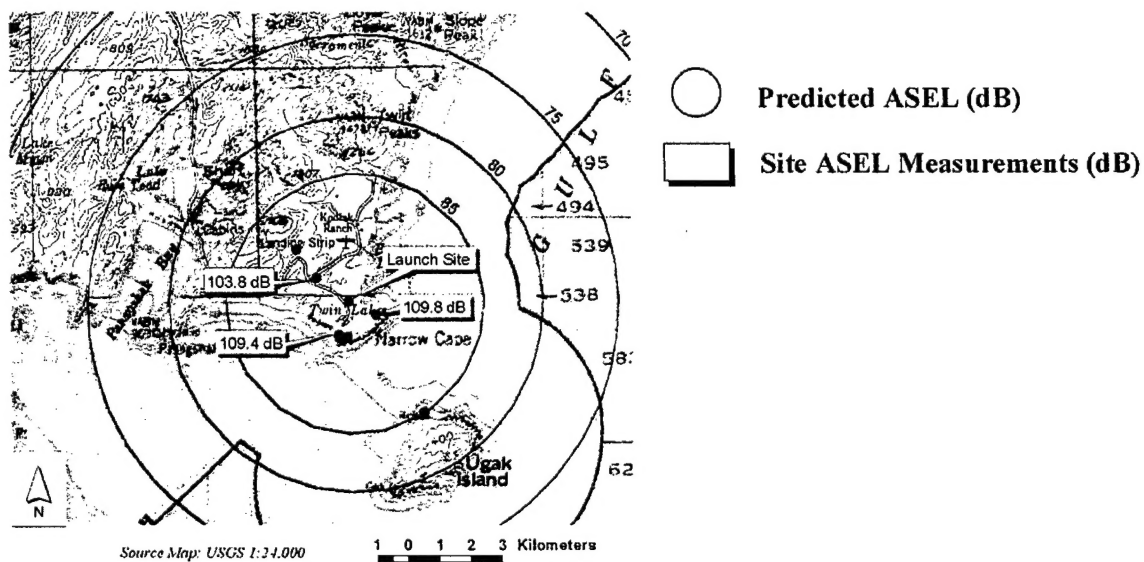
## 5.2 ait-2 Launch, September 1999

Steller sea lions were present at the Ugak Island haulout (shown in Figure 1) during the ait-2 launch period in September 1999. Approximate counts of the sea lions were made on three occasions prior to the launch. The logistics of these observations are described in *Lang, 2000*. The highest count of sea lions was 37–45 individuals, 3 days prior to launch. The sea lion haulout is approximately 5.7 km from the launch site.

Figures 4 and 5 show representative data from the ait-2 noise monitoring effort compared to sound pressure levels predicted with RNOISE. The complete set of HSWRI data and its analysis is given in *Bowles, 2000*. As mentioned earlier, C-weighted and unweighted sound pressure levels are included in *Bowles, 2000*, but only representative A-weighted data are shown here. The average background level ( $L_{eq}$ ) noise level on Narrow Cape (average of two measured sites) was 49.3 dB(A). Ambient levels on Ugak Island should have been comparable. The measured ASEL values on Narrow Cape

were 109.8 at 1.26 km from the launch site; 109.4 at approximately 1.47 km; and 109.7 dB at approximately 1.72 km from the launch site. Similarly, the measured  $L_{AMAX}$  levels were 103.5 dB, 105.3 dB, and 109.7 dB at the same locations. This does not indicate a clear decrease in sound levels with increased distance from the launch event. The HSWRI recorder on Ugak Island malfunctioned; however, a recorder deployed by ENRI recorded an ASEL of 92.2 dB and an  $L_{AMAX}$  of 81.5 dB (Bowles 2000). It should be noted that the ENRI instrument was not calibrated to the HSWRI instruments. The Ugak Island monitoring site is 5.7 km from the launch site. Sound event durations for ait-2 are given in Bowles, 2000.

The RNOISE predictions generated contour lines (Figures 4 and 5) that show a decrease in amplitude with increasing distance from the launch site. This same trend was not evident in the measured ait-2 sound levels. A sound level contour line predicted with RNOISE intersects the Ugak Island sea lion haulout and monitoring site. The RNOISE-predicted ASEL of 85.1 dB for that site is slightly lower than the ENRI measurement of 92.2 dB. The RNOISE predicted  $L_{AMAX}$  for that site is 73.4 dB. The actual measured ENRI  $L_{AMAX}$  of 81.5 dB is also somewhat higher than the prediction.



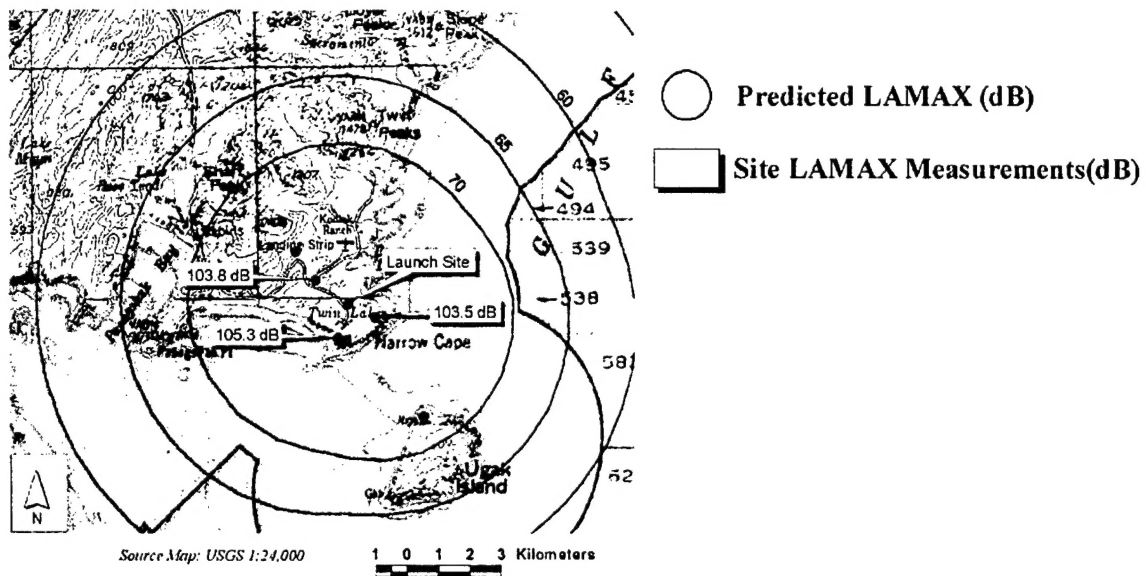


Figure 5. ait-2 predicted vs. measured A-weighted maximum sound pressure levels ( $L_{AMAX}$ ). RNOISE predictions made by K. Plotkin of Wyle Labs and the sound pressure levels recorded by A. Bowles of HSWRI.

## 6. Discussion

Comparisons of the monitoring results with RNOISE predictions indicate that for the limited ait-1 and ait-2 cases, the ASEL predictions more closely correspond to the measurements than do the  $L_{AMAX}$  predictions. This is an indication that the A-weighted sound exposure levels, which are integrated over time, are not as sensitive to variables that may differ between the predictions and the actual launch. For example, a uniform atmosphere meteorological profile was used in making the RNOISE predictions. However, ground-level wind speed and direction, temperature, and other factors may affect the actual measured sound levels. Terrain may also contribute to interference or enhancement of sound transmission. The terrain surrounding the Narrow Cape launch site contains several gullies, hills, and various levels of coverage by trees. Between the launch site and Ugak Island, the terrain varies from land to ocean with varying degrees of humidity and winds. The RNOISE predictions did not account for these factors. Any differences between the modeled trajectories and the actual flight trajectories should not noticeably affect the differences between RNOISE predictions and measured sound levels since the noise event of interest occurs when the vehicle is on the pad or vertically over it. Down-range variations in the trajectory occur when the sound levels have dropped significantly.

Both ASEL and  $L_{AMAX}$  were apparently underestimated by RNOISE for the ait cases. However, RNOISE predictions were, in all cases, within 8 dB of the measured sound levels. This is within the expected uncertainties of the model since the RNOISE computations are largely based on predicted vehicle performance parameters, a uniform atmosphere, and flat terrain. Many NEPA analyses must be completed prior to the availability of actual flight data. For new launch systems or for geographic locations that are difficult to access, RNOISE can provide valuable predictions of noise levels. Understanding the limitations of predictive models and any systematic trends in the calculations allows for improved application of the models.

## 7. References

Alaska Aerospace Development Corporation and Federal Aviation Administration, Environmental Assessment of the Kodiak Launch Complex, June 1996.

Alaska Aerospace Development Corporation, Natural Resources and Management Plan (NRMP) for the Kodiak Launch Complex, June 1998.

Bowles, A., HSWRI Noise Monitoring, ait-2, Final Report, May 2000.

Department of the Air Force, Environmental Assessment for U.S. Air Force atmospheric interceptor technology Program, November 1997.

Lang, V. I., ait-2 Launch Observations at Kodiak Launch Complex, The Aerospace Corporation, Aerospace Report No. TOR-2000(1306)-1, 2000.

Richardson, W. J. et al., Marine Mammals and Noise, (Academic Press, 1995) p. 205-240.

Stewart, B. S., Evaluation of the potential impacts of launches of the USAF atmospheric interceptor technology (ait) test vehicle from the Kodiak Launch Complex (KLC) on threatened and endangered species of wildlife. Launch of ait on 5 November 1998, 1632 hrs PST; Noise Monitoring Results. HSWRI Technical Report 99-291, 1999.